Project Introduction

In fluid dynamics, the limits of continuum mechanics are surpassed when the mean free path of molecules becomes equivalent to the characteristic length scale. This can occur in hypersonic transition when molecular scales are equivalent to roughness height, during atmospheric entry, in spacecraft attitude control plumes, and in the small dimensions of micro- and nano-scale devices. Within these regimes, the Boltzmann equation must be solved to accurately model the physics. Methods such as DSMC have been developed to provide solutions to the equation. However, DSMC has difficulty simulating complex gas models with unsteadiness, intricate geometry, or chemistry. It also tends to produce noisy solutions that are difficult to couple with continuum solvers. New discrete velocity methods which require less computational cost and produce less statistical noise are being developed as an alternative to DSMC. The problems with DSMC can be addressed by a discrete velocity method if the Boltzmann equation is solved using several key innovations recently developed at the University of Texas. The results provide the exciting prospect of efficient, cost effective, quiet, and accurate solutions to the Boltzmann equation. The current innovations utilize a statistical method called variance reduction where properties of equilibrium distributions are used to greatly reduce statistical noise and reduce computational time. A second key innovation is a method for allowing arbitrary post-collision velocities to be mapped back onto a discrete grid in velocity space. Both innovations opened the door to my development of a solver utilizing non-uniform velocity grids and schemes for moving a distribution function between different velocity grids. I propose to advance the current discrete velocity model to a version that handles adaptivity in the velocity grid and includes rotational and vibrational internal energy. Velocity grid adaptation will greatly enhance the ability of a discrete velocity code to produce more accurate results for any quantity of interest. The inclusion of internal energy better represents physical reality, and with internal energy included, multiple species can be used in simulations. Accurate representation of the distribution function allows for more accurate and efficient simulations. The discrete velocity method I develop will be a large step towards a fully capable flow solver that can be coupled with continuum solvers to correctly model flow with rarefied gas effects. The increased accuracy without exorbitant cost addresses NASA's strategic goals by allowing easy access to computational solutions.

Anticipated Benefits

The discrete velocity method I develop will be a large step towards a fully capable flow solver that can be coupled with continuum solvers to correctly model flow with rarefied gas effects. The increased accuracy without exorbitant cost addresses NASA's strategic goals by allowing easy access to computational solutions.

Project Image A Novel Highly Efficient Scheme for the Boltzmann Equation

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Organizational Responsibility

Responsible Mission Directorate:

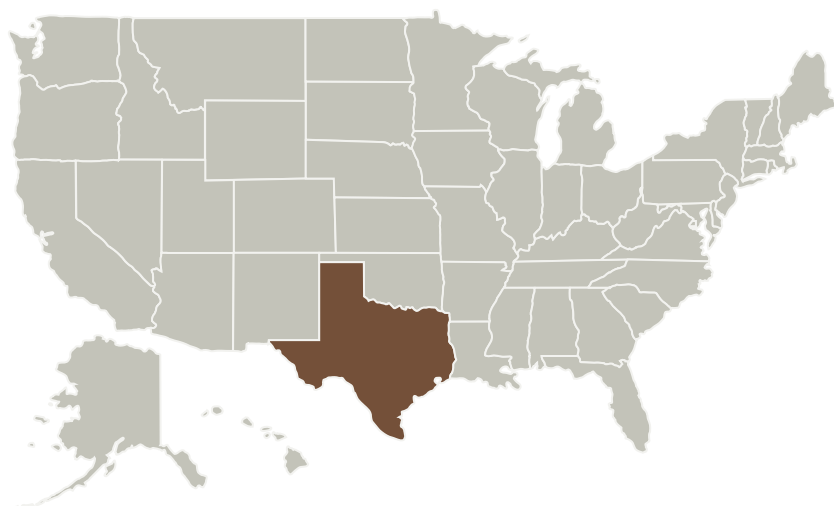Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

Primary U.S. Work Locations and Key Partners

Organizations Performing Work	Role	Type	Location
The University of Texas at Austin	Supporting Organization	Academia	Austin, Texas

Primary U.S. Work Locations
Texas

Project Management

Program Director:
Claudia M Meyer

Program Manager:
Hung D Nguyen

Principal Investigator:
Phillip Varghese

Co-Investigator:
Peter P Clarke

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**

1	2	3	4	5	6	7	8	9
Applied Research			Development			Demo & Test		
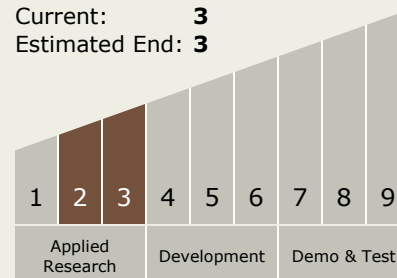
Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  - TX09.4 Vehicle Systems
    - TX09.4.5 Modeling and Simulation for EDL

Images

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Project Image A Novel Highly
Efficient Scheme for the Boltzmann
Equation
*(https://techport.nasa.gov/imag
e/1713)*

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html